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THE CASE FOR TEACHING FUNDAMENTAL COMPUTER TECHNOLOGY BY SUBJECT MATTER PROFESSIONALS USING PROGRAMMABLE CALCULATORS

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ABSTRACT

This paper describes an approach to teaching basic data processing techniques in specific subject matter areas using programmable calculators. The Texas Instruments Model 59 programmable calculator provides undergraduate students with an extremely low-cost means of gaining 'hands-on' experience with computer hardware and software. A survey of students taking the course indicated students felt the effort expended in the course was high relative to other courses but expressed a high degree of satisfaction with the course, with the availability of the miniature computers and with the perceived future personal utility of the course. The authors conclude that teaching fundamental computing techniques with programmable calculators in specific subject matter areas may be more effective than requiring students to receive instruction based on large, mainframe computers in computer science departments.

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I. Introduction

In 1972, Charles E. French, then Chairman of the Department of Agricultural Economics at Purdue University stated:

> Historians may not fully concur, but certain engulfing urges seem to sweep through our economic and social system from time to time. These become societal prime movers. Some such urges can be identified, e.g. the urge to explore, the urge to mechanize, the urge to organize, the urge to accelerate, and the urge to socialize. Two or more of these may interface at times. Cybernetics seems to be such a prime mover balanced on modern urges to industrialize and accelerate. In this sense it is profound and powerful among events of our time and has influenced agriculture (society) positively. (French, 1972)

Rapid development of data processing equipment and procedures over the past decade literally has placed the power of computers, the basic component of cybernetics, into the hands of anyone. We have become the 'computerized society.'

This pervasive impact of cybernetics on society presents a unique challenge to the educational community. In fact, the National Science Foundation stresses that due to the high potential for influencing the nation positively, teaching students with scientific majors basic computer principles and concepts should receive high priority for use of educational resources over the next decade (National Science Foundation, 1979). The Foundation concludes that development of appropriate educational programs is not only desirable, but inevitable and that federal funds and influence should be expended to accelerate the process.

While the National Science Foundation stresses the need for educating students with scientific majors in computer technology, the same needs can be implied for students in other fields of study.

II. Statement of the Problem

In the broadest context, the authors feel the most pressing problem facing the educational community is to prepare students to cope with a world of diminishing natural resources wherein the costs of extracting those resources, with any given technical base, continues to increase. Cybernetic technology seems to be a basic ingredient of practically all emerging technologies that might have the combined capacity of maintaining or improving standards of living. It is also the authors' contention that educators in practically every field of study from the sciences to the liberal arts have the opportunity to improve quality of education in their field by greater implementation of presently available cybernetic technology, which can be done, in most cases, at very low cost.

Traditionally, subject matter departments have turned to computer science departments to train students in data processing procedures. Computer science departments usually use large, expensive, mainframe equipment. Students normally gain access through preparation of paper cards and/or other media and subsequent batch processing or by time-sharing through strategically located terminals. Emphasis is usually placed on training students to become programmers and/or computer scientists. It is the authors' contention that students of agriculture and probably other subject matter oriented students tend to shun such courses. Thus, the percentage of students graduating from institutions of higher learning having fundamental data processing training remains low.

While the above approach was probably valid in a time when computer equipment was expensive, sensitive, and difficult to use, the authors contend that every student should gain a basic concept of modern data processing technology and that these concepts can be most effectively taught by subject matter professionals. Computer equipment has been miniaturized, been made easier to use, become less expensive and improved in reliability. With these improvements, fundamental data processing techniques and applications can now, in many cases, be taught more efficiently by subject matter professionals thereby reserving computer science departments and their large, mainframe computers for the training of computer scientists, further education of other subject matter students desiring advanced data processing techniques and for researching methods of data processing. This shift could have the potential for educating a greater number of students, in a more effective way, in the methodologies of incorporating cybernetic technology into their various subject matter areas, thus enabling them to become more effective problem solvers.

III. Objectives of the Paper

Objectives of the paper are to present:

1. A brief description of programmable calculator technology and the potential for using it to

educate students on fundamental computer technology.

2. A description of a course designed and taught by the authors to teach basic computer technology and applications to agricultural students.

3. An evaluation of the course as to its effectiveness in meeting course objectives.

4. Implications for professionals in other subject matter areas.

IV. The Technology

A. Historical Perspective

Present computers operate thousands of times faster than the first models and at a fraction of the cost per unit of work accomplished. They are also easier to access; more accurate and reliable; simpler to program; less sensitive to environmental conditions; and occupy less space per unit of capacity.

Two developments of special significance to small users have been time-sharing and the advanced programmable calculator (hand computer). Time-sharing, in its broadest sense, allows one almost instant access to computer programs and data banks at any location from any location. All that is needed is a terminal, a telephone, electrical current, and a contract with the appropriate computer center (Taylor, 1976). This development of the late 60s and early 70s was especially significant to educators and small businessmen since it gave them access to computer technology at dispersed locations at relatively low cost.

Battery powered, hand-held calculators first became available in the early 1970s. Technology has been advanced rapidly so that now some programmable calculators are sophisticated computers. Even more startling technological improvements lie ahead. Experts predict VLSI (Very Large Scale Integration) will make it possible, perhaps within five years, to compress the number-handling proficiency of a present-day, large computer into a single part about the size of a match head. The advent of such 'superchips' could prove to be the technological equivalent of the leap from transistors to integrated circuits in the early 1960s (Shaffer, 1979).

Even now many programs previously available to the small user only through time-sharing can be adapted for use on programmable calculators. These units are particularly attractive in that they provide access to computer capability at very low cost. An advanced programmable calculator can be purchased for about $200, a compatable printer for about $150, and exchangeable modules of programs for about $35 each, for a total outlay of less than $500 for most users. Costs of operation are negligible.

B. Characteristics of Advanced Programmable Calculators Enabling Students to Meet Educational Objectives

Advanced programmable calculators, recently developed, hold promise as a means to help meet a multitude of educational objectives. New models may be programmed by the user and allow preservation of programs and data on read/write media, have solid state exchangeable program modules, allow upward compatibility in both learning and new hardware introduction, are low cost, portable, and offer versatility in usage. The unit discussed in this paper as an example of programmable calculators is the Texas

Instruments Model 59. Models with similar capabilities are available from other manufacturers.

Programmability is the most attractive feature of these units. Fairly sophisticated programs can be developed and executed. Because the units can be programmed, students using a TI-59 or similar programmable calculator can write, code, and execute programs. The graphic representation of the problem to be solved, i.e. the flowchart, takes on new meaning when program steps and data are entered into the unit. Execution provides immediate feedback to students. Applications requiring numerous calculations can be handled with little difficulty. However, the small memory compared to more sophisticated computer systems does place an upward limit on the number of programming steps and the amount of data that can be entered.

Late model programmable calculators allow users to save programs and the contents of memory registers on read/write media, magnetic cards in the case of the TI-59. This means users can save for future use an unlimited number of programs. To solve a particular problem, a user loads a program into the hand computer simply by having the unit read magnetic cards. Data may be entered by hand or from magnetic cards.

Commonly used programs are often available on modules, each containing about 25 programs. These programs or portion of them can be used individually in program solving and can also be used as 'subroutines' in individually written programs. This subroutine capability greatly increases the potential scope of user written programs.

Concepts and skills learned and developed by students in working with hand computers ease the transition to mini-computers, time-sharing, and mainframe units. For example, in using the programmable calculator, students must assign locations for both instructions and data and make provisions for recall from assigned locations. This requirement, which in a large computer is automatically handled by a compiler, makes students more aware of basic computer operations.

Manufacturers intend to maintain upward compatibility in new hand-held computer models of the future. The new units will utilize many features of present models, for example key layout. Students becoming proficient in the use of present models should find little difficulty in upgrading to newer, more powerful equipment.

Educators are constantly reminded of budget limitations. Compared to other automatic data processing equipment, the cost of providing 'hands-on' experience with programmable calculators is very low. Cost comparisons will be made in a later section.

Providing students with what amounts to their own personal computer adds greatly to their interest in and satisfaction with a basic computer education course. Portability of the units means they can be used in different classrooms and even can be checked out of the library on demand by students. For example, the TI-59 weighs less than a pound and can operate for about three hours on a battery charge.

Versatility of programmable calculators also adds satisfaction by enabling students to acquire knowledge from a preexisting base since nearly all have used simple hand-held calculators. A programmable calculator can be used by students simply as a calculator or as a computer using internal programs contained in exchangeable moduels, programs developed by others which are entered by coding, and programs written by students themselves. This progression on the machines from use as a calculator to self-programming can ease student transition into the sometimes intimidating world of computers.

An important factor in any computer system is availability of appropriate programs for use in solving problems. Fortunately, development of programmable calculator programs has been rapid. Many programs written for other computer systems have been adapted to the compact units.

Solid state exchangeable library modules presently available on the TI-59, for example, include: master, agriculture, applied statistics, real estate and investment, aviation, marine navigation, surveying, leisure, securities analysis, business decisions, and custom. Additional library modules are being developed as demonstrated demand is sufficient to justify costs of introduction. Programs presently available on exchangeable modules provide users a wide range of applications in many different subject matter areas (Texas Instruments, Inc. 1977).

In addition to the modules, Texas Instruments offers specialty packets which are collections of programs designed for special interest groups. The user simply keys the desired program into the unit. Finally, one can join user groups wherein an individual may both contribute and receive programs.

V. The Course 'Computers in Agricultural Decisions"

A. Educational Objectives

The basic problem in the College of Agriculture and Home Economics at The Ohio State University was to provide students a working knowledge of applied computer techniques they could use in upper level courses, graduate level courses and on the job. They did not need the depth and breadth of training a sequence of computer science courses might give them. But still they needed to know the elements of data handling in information systems; they needed to be acquainted with computer system components and understand the appropriate terminology; students also needed some knowledge of basic computer programming to enable them to better understand computerized problem solving approaches.

The course that evolved from this set of needs is 'Computers in Agricultural Decisions.' The overall objective of the course is to develop in students the ability to solve agricultural decision-making problems with the help of computer systems. The problem solving approach is taught as a four-step sequence: 1) problem analysis; 2) flowchart application; 3) coding and executing the program; and 4) documentation.

The specific educational objective in problem analysis is for students to demonstrate an understanding of the role computer systems can play in the recognition of a problem, identifying the cause of the problem, and anlyzing alternative solutions. Emphasis is placed on the design of feasible management information systems.

A second educational objective is to develop the ability to use program and system flowcharting techniques in problem solving. Students use the four major flowcharting techniques--initialization, looping, developing a sum, and developing a counter to formulate a graphic representation of operations and decision logic required to solve problems in their particular agricultural specialties.

A major portion of the course is devoted to the third step in problem solving--coding and executing the program. The specific educational objective here is for students to demonstrate a working knowledge of software elements and hardware components that make up computer systems. Studying computer number systems, languages, and programming contribute to the objective. Comparison of design characteristics and capabilities of various computers (e.g. mainframe systems, time-sharing, mini-computers, and hand-held units) also aids students in reaching this specific education objective. As they organize information for decision making, students come to recognize the importance of documentation, the fourth and final steps in problem solving.

B. Anatomy of the Course

Enrollment is limited to 86 students (room capacity) each quarter with student demand exceeding capacity most quarters. All students meet together three periods per week for lecture. The class is then divided into four groups, based on subject matter interest, for discussion/laboratory periods. The course attracts students from all agricultural subject matter areas thus creating a heterogeneous class composition (Table 1). To reduce problems caused by heterogeneity, the class is divided into separate discussion/laboratory sections. Sections include horticulture, animal industries, crop production, and agricultural business. Each group meets once a week for a two-hour period. Students are required to purchase two texts. The first, Introduction to the Computer: The Tool of Business is used to introduce them to basic computer concepts (Fuori, 1977). The second, Programmable Calculators: Business Applications is specific to the equipment being used (Aronofsky, 1978).

Experience has shown that an ideal complement of equipment for the course is 15 programmable calculators with an agricultural module for each and 10 compatible printers. This allows one calculator for each two students in discussion/laboratory sections, one for the instructor, and three spares to handle unusually large sections and to replace units being repaired. McGrann and Edwards, in their extension education experience also found one calculator for each two participants in workshops to be ideal (McGrann, 1979). The major utility of printers is in writing and debugging programs. When the equipment is not being used in discussion/laboratory sessions, it is made available to students through the Agriculture Library's closed reserve system. Students are able to check out a 'computer packet' (Table 2) anytime the library is open and units are available. Use is restricted to the library.

A term project of ten to twenty pages plus an oral presentation of the project is required of each student. Students may choose any topic, broad or narrow, that relates concepts and techniques taught in the course to their personal area of interest. Most students use existing programs or write special programs for the programmable calculator as a portion of their term projects. Each student is allocated ten minutes in a special interest discussion/laboratory section to present a summary of the term project.

For discussion purposes, the course sequence can be divided into three parts: 1) introduction to programmable calculators, programming, problem solving, and automatic data processing; 2) computer languages and more advanced programming; 3) basic computer principles.

The equipment and its operation effectively attracts the students' attention. To take advantage of this, students are introduced to the programmable calculator in the first discussion/laboratory section. In a workshop setting students are asked to store values in memory registers, perform mathematical calculations, recall specific values from appropriate registers, and then accumulate results in still other memory registers. This approach gives students a taste of data processing, introduces them to the equipment, and builds rapport between the instructor and students as well as among students.

Next, students learn simple programming on the programmable calculators. Students learn that a program is simply a method of getting the equipment to do the work of pressing buttons and writing down intermediate results rather than humans doing it. In the discussion/laboratory periods, students are assigned to write a simple program to do the same mathematics done manually the previous week.

Students then learn to use magnetic cards to store programs and data off-line and to use the printer. After writing and debugging programs without these accessories, students appreciate their contribution. With this background students are introduced to flowcharting in modeling as an approach to problem definition and analysis. The previous work with the programmable calculator serves as a bridge to relate flowcharting symbols to identifiable programming steps.

The middle third of the course concentrates on programming and applied problem solving. Students are first introduced to the general framework of computer languages. Next, they learn more sophisticated programming which includes internal decision making through maintaining a counter, branching, and looping. Discussion/laboratory sections are devoted to application problem solving and one major assignment wherein each student writes a fairly sophisticated program on the calculator, using the techniques learned, to solve an agricultural problem.

The final third of the quarter is spent learning basic computer principles. After students become proficient operators and problem solvers using programmable calculators, they seem to have little trouble transferring similar procedures to more sophisticated equipment. In this section, students are introduced to computer number systems, the history of computers, processing and storage devices, input/output media and devices, advanced computer concepts and anticipated future developments. The BASIC language is introduced at this point to demonstrate the similarities and differences between machine specific and high level computer languages. Discussion/laboratory sections are devoted to programming in BASIC. Students are given the opportunity to run programs they have written on a mini-computer and a time-sharing terminal. The remaining discussion/laboratory sections are reserved for term project oral presentations by students.

VI. Evaluation

The course can be evaluated from the standpoints of: (1) Were students able to learn fundamental data processing principles? (2) Were they able to apply these concepts to their agricultural specialities? (3) Did they make extensive personal use of the programmable calculators? (4) How did students evaluate the course as to preparing them for their futures? (5) Were the educational objectives met in a cost effective manner?

First, students were able to master fundamental data processing principles by the use of programmable calculators. This was demonstrated through the testing procedure. The flowcharts and programs were developed so that a student would have to have mastered the concepts of developing a counter, developing a sum, initializing, looping, conditional branching, unconditional branching, use of subroutines, etc. Tests were designed to require students to correctly interpret both flowcharts and various computer programs in order to receive a passing grade. In addition, homework problems were designed to build this capability.

Second, students demonstrated their ability to relate this technology to their agricultural specialities through term projects. The term project requires that students research and write papers on topics in their subject matter areas. Many students write programs for the TI-59 to solve specific problems in their area of interest. The papers, plus oral presentations during the discussion/laboratory sections have convinced the authors that the majority of students develop the ability to incorporate data processing concepts into their speciality areas of interest.

To determine student reaction to the course, end of quarter student surveys have been conducted for each quarter the course has been taught since adopting the TI-59 as the main educational medium, Spring Quarter 1979. The results from Autumn Quarter 1979 are probably the most representative as related to how the course is now taught. Extensive revisions were made between the Spring and Autumn Quarters of 1979. All but two of the 76 students completing the course Autumn Quarter 1979 made evaluations. Students were enthusiastic about the use of the programmable calculator. All but one rated it as either essential, very important, or important when asked "How important was access to and utilization of the TI-59 to your comprehension of computers and their present and future utilization in agriculture and society?". Eighty-six percent of all students ranked it in the top five when asked "Compared to all other courses you have taken at Ohio State, how would you rank 'Computers in Agricultural Decisions' as to its utility in preparing you for your future?" (Table 3). Students also found the course demanding. When asked "Compared to all other courses you have taken at Ohio State, how would you rank 'Computers in Agricultural Decisions' as to the amount of effort required to meet course objectives?", ninety-seven percent ranked it in the top five. Students reported spending an average of 69 hours studying outside of the classroom on the five-hour course with very little difference noted for class rank. Over half of the outside time was spent operating the calculators (Table 4). Approximately sixty percent of the students felt the course should be required for all agricultural majors.

Students made extensive personal use of the programmable calculators. During Autumn Quarter 1979, they reported spending an average of 38 hours per student in the agricultural library operating the units in addition to about ten hours each expended during the discussion/laboratory periods. It is estimated that between five and ten students purchase their own units each quarter.

Teaching fundamental computer technology and subject matter applications by this method is very cost effective. Total cost of equipment for the course was about $5500 (Table 5). Annual cost is estimated to be about $2200 (Table 6). Based on average use of 43 hours per student, the direct cost per hour was about twenty cents. This twenty cents per student hour is a small fraction of the cost of providing 'hands-on' experience through time-sharing. Indirect costs such as library expenses and electricity were not included.

The reader should be aware of the limitations of the evaluation approach and methodology. First, we had no way of comparing the degree of learning students attained compared with what they might have attained by taking a course through the computer science department. Second, since similar student surveys were not conducted no comparisons could be made to years before the TI-59 programmable calculator was introduced (the course has been taught since 1972). Third, the course has evolved quarter by quarter so that data collected for one specific quarter, for example, is not strictly comparable to data collected in adjacent quarters. In spite of these limitations, the authors feel evaluations have conclusively shown that fundamental computer technology and its applications can be effectively taught by subject matter professionals in a very cost effective manner. Furthermore, they believe that it can be taught more effectively in this environment than in computer science departments.

VII. Implications, Recommendations and Conclusions

Recent developments in programmable calculator technology added a needed dimension to teaching computer technology. Programmable calculators provide educators the means to provide students with almost unlimited, 'hands-on' experience with both computer hardware and software at low cost. Programmable calculators provide an excellent tool for teaching basic computer concepts and applications in various subject matter areas. Students can write programs to fit specific applications or use programs already developed. Courses taught using programmable calculators can provide students with knowledge and skills which serve them well in other courses and after graudation. This technology allows subject matter professionals to teach fundamental data processing techniques to their students using data and information with which the students are familiar.

The authors are convinced that teaching fundamental computer technology in a subject matter environment will encourage larger numbers of students to become acquainted with modern data processing techniques.

Based on The Ohio State University experience, the following recommendations to educators contemplating similar courses are offered by the authors. First, if class composition is heterogeneous, create subject matter oriented discussion/laboratory sections each limited to 25 students. Small subject matter groups create good rapport between instructor and students and also among students. The group approach also aids learning by allowing students more time to concentrate on areas of specialization. Second, provide adequate equipment to maximize 'hands-on' experience. This can be accomplished at relatively low cost by using programmable calculators. Third, anticipate and prepare for increased demand for the course. As the need for this type of education is felt by students and educators in a discipline demand will increase for the course and for additional subject matter oriented discussion/laboratory sections.

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Table 1. Selected Characteristics of Students Completing 'Computers in Agricultural Decisions,' Spring and Autumn Quarters 1979.

	Quarter	
	Spring	Autumn
Number of Students	68	76
Class Rank	Percent	Percent
Seniors	30	32
Juniors	32	30
Sophomores	26	38
Freshmen	12	0
Major	Percent	Percent
Animal Science	30	18
Agricultural Economis	29	28
Horticulture	16	22
Agricultural Education	10	9
Dairy Science	4	4
Agronomy	4	7
Agricultural Communications	3	4
Poultry Science	2	0
Agricultural Mechanization and Systems	2	8
Sex	Percent	Percent
Male	68	66
Female	32	34

Table 2. Materials Included in Library Check-Out Packet

Vinyl Portfolio Transport Case (Hazel G8-R105-46)
Programmable Calculator (Texas Instruments TI-59)
AC adapter/charger 120 Vac
Master Library Book with Module
Agricultural Library Book with Module
Personal Programming Book provided by The Equipment Manufacturer
Programmable TI-58/59 Solid State Software Libraries and Other Accessories Booklet

Table 3. Student Response by Class Rank to the Question "Compared to all other courses you have taken at Ohio State how would you rank 'Computers in Agricultural Decisions' as to its utility in preparing you for your future," Autumn Quarter 1979.

Rank	Overall		Class Rank					
			Sophomores		Juniors		Seniors	
	F[a/]	C[b/]	F	C	F	C	F	C
First	12	(12)	23	(23)	05	(05)	05	(05)
Second	20	(32)	19	(42)	22	(27)	18	(23)
Third	35	(67)	27	(69)	43	(70)	36	(59)
Fourth	11	(78)	19	(88)	05	(75)	09	(68)
Fifth	8	(86)	04	(92)	17	(92)	05	(73)
Less Than Fifth	14	(100)	08	(100)	08	(100)	27	(100)
	---------------------- percent ------------------							

a/Frequency percentages.

b/Cumulative percentages.

Table 5. Capital Investment for Data Processing Equipment and Costs for Depreciation, Repairs, and Replacement.

Item	Cost[a]	Life Length years	Yearly Depreciation[b]	Yearly Repairs and Replacement[c]
Programmable calculators (Texas Instruments-TI-59) 15 @ $204.00	$3060.00	5	$ 612.00	$459.00
Printers (Texas Instruments-PC-100C) 10 @ $148.00	1480.00	5	296.00	222.00
Agricultural module (Texas Instruments/ Iowa State) 15 @ $37.50	562.50	5	112.50	84.37
Portfolio transport cases 15 @ $14.06	210.90	5	42.18	31.64
Extension Cords	50.00	5	10.00	7.50
TOTAL	$5363.40		$1072.68	$804.51

[a]Actual 1979 costs.

[b]Zero salvage value.

[c]15% per year.

Table 4. Average Grade Point and Reported Nonclassroom Student Time Expended on the Course, Autumn Quarter, 1979.

Item	Total	Class Rank: Sophomores	Juniors	Seniors
Number of Students Reporting	71	26	23	22
Average Grade Point[a]	2.9	2.9	2.9	2.9
Average Total Hours Expended Outside the Classroom	69	75	60	70
Average Hourse Expended Outside the Classroom Operating the Programmable Calculators	38	42	32	39

[a] Based on a four point system (A=4, B=3, C=2, D=1, E=0)

Table 6. Annual Costs, Costs per Student Hour Taught, and Costs per Hour of 'Hands-on Experience.'

Item	Annual Cost	Cost per Student Hour Taught[a]	Cost per Hour of 'Hands-on Experience'[b]
Fixed Costs			
Depreciation	$1072.68	$0.84	$0.10
Repairs and replacement	804.51	0.63	0.17
Variable Costs			
Printer paper 100 rolls @ $3.40	340.00	0.27	0.03
TOTAL	$2217.19	$1.74	$0.20

a/ 85 Students x 5 hours x 3 quarters = 1275 hours.

b/ Estimated at 10,965 hours per year or 43 hours per student.